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RESEARCH MEMORANDUM

THE BEHAVIOR OF BERYLLIUM AND BERYLLIUM COPPER

IN A 4,000° F SUPERSONIC AIR JET AT A

MACH NUMBER OF 2

By William H. Kinard

Langley Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

October 16, 1957

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SUMMARY

A preliminary investigation was conducted in a 4,000° F supersonic air jet at a Mach number of 2 at the Langley Aeronautical Laboratory to investigate the behavior of beryllium and beryllium copper. Conical models with 10° half-angles of both materials with sharp points and with 0.064-inch nose radius were tested.

Results of these tests indicate that the beryllium is superior to beryllium copper as a heat-sink material. No burning was observed during the test of either material.

INTRODUCTION

The analysis given in reference 1 indicates a possible solution to the problem of survival for long-range ballistic missiles by the use of a high-drag configuration with a thick skin capable of absorbing the heat input. Of the known metals, beryllium is one of the more desirable as a heat-sink material because of its high heat capacity per unit mass. It has approximately 6 times the heat capacity of copper on a weight basis and 1.3 times the capacity on a volume basis; however, the resistance to oxidation of beryllium in a high-temperature air jet was unknown.

The purpose of the present investigation was to observe the behavior of beryllium in a 4,000° F jet and to compare its behavior with that of beryllium copper. This investigation is part of a general research program to obtain information on a large number of materials.

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MODELS AND TESTS

Figure 1 shows the four models tested in this investigation. Model 1, a 10° half-angle cone with a sharp point, and model 2, a 10° half-angle cone with a nose radius of 0.064 inch, were made from chemically pure beryllium. The beryllium models were mounted in graphite adaptors. The beryllium-copper models, model 3 (the same configuration as model 1) and model 4 (the same configuration as model 2), were made from an alloy of approximately 2 percent beryllium and 98 percent copper. A beryllium-copper model was used since it was more readily available than a pure copper model and should behave in a similar manner. The beryllium-copper models were mounted in stainless steel adaptors with Bakelite insulators. Physical properties of beryllium and beryllium copper are given in table I.

The models were tested in the ceramic heated jet (laboratory model) which was operated at $4,000^\circ$ F. A description of this facility is contained in reference 2. The models which had the 0.064-inch nose radius were subjected to a calculated heating rate of approximately 900 Btu/sq ft/sec at the start of the test and the heating rate of the sharp-pointed models was higher.

The tests were recorded on 16-mm Kodachrome film.

DISCUSSION

The two beryllium models and the two beryllium-copper models tested in this investigation showed no burning.

The sharp-pointed beryllium model remained in the jet for 0.2 second before melting was observed and the sharp-pointed beryllium-copper model started melting at 0.05 second. The beryllium model of 0.064-inch nose radius began melting at 2.9 seconds and the same configuration made of beryllium copper began melting at 1.6 seconds. The beryllium model not only remained in the jet longer before melting occurred, but the rate of melting was much lower than for the corresponding beryllium-copper models. These differences in melting behavior are shown in figure 2, which shows the damage after 1 and 2 seconds in the airstream.

Based on past experience in testing models on many different types of adaptors, it is believed that the differences between the adaptors of the beryllium models and those of the beryllium-copper models had little effect on the melting rates of the two materials. The high resistance of the physical joint between the models and the adaptors created the largest barrier to conduction of heat away from the models.

CONCLUDING REMARKS

Beryllium and beryllium copper did not burn during the test conducted in a 4,000° F supersonic air jet. The beryllium proved to be superior to beryllium copper as a heat-sink material evaluated on both a volume basis and a weight basis. The rate of ablation of beryllium was less than half the ablation rate of beryllium copper after initial melting began.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 23, 1957.

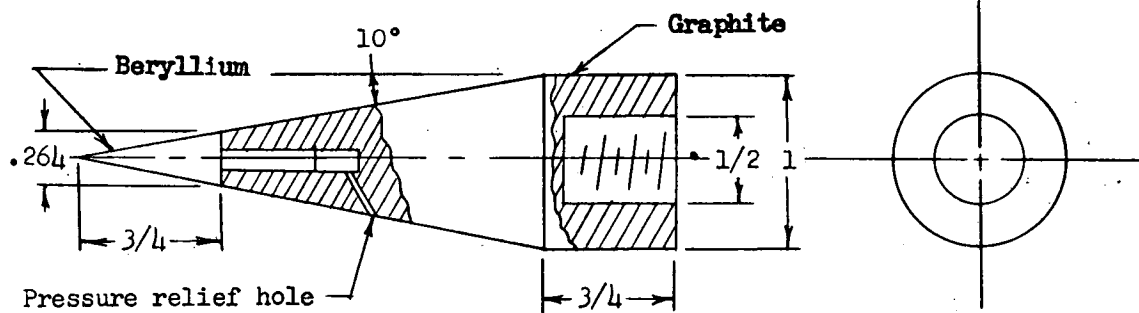
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1. Allen, H. Julian, and Eggers, A. J., Jr.: A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds. NACA RM A53D28, 1953.
2. Purser, Paul E., and Hopko, Russell N.: Exploratory Materials and Missile-Nose-Shape Tests in a 4,000° F Supersonic Air Jet. NACA RM L56J09, 1956.

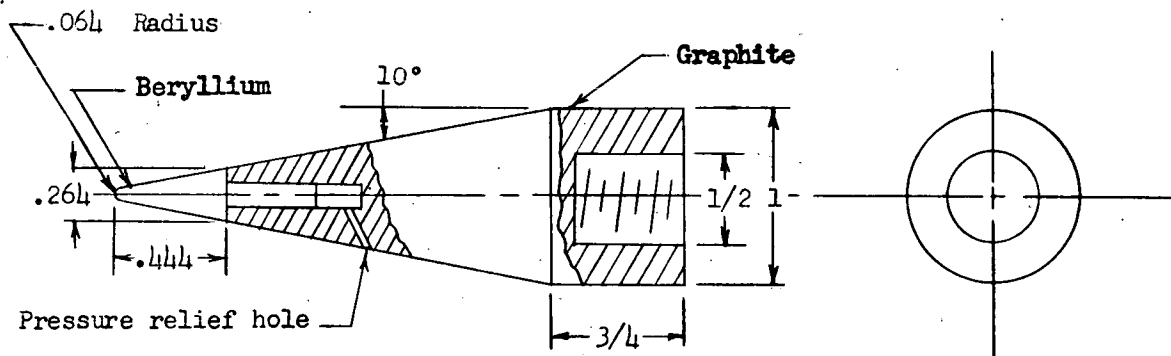
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TABLE I
PROPERTIES OF BERYLLIUM AND BERYLLIUM COPPER

	Beryllium	Beryllium copper
Melting temperature, °F	2,343	1,587
Specific heat, Btu/lb/°F	0.516	0.1
Thermal conductivity, Btu/sq ft/in./°F/sec	0.20	0.16
Density, lb/cu in.	0.066	0.297



Model 1

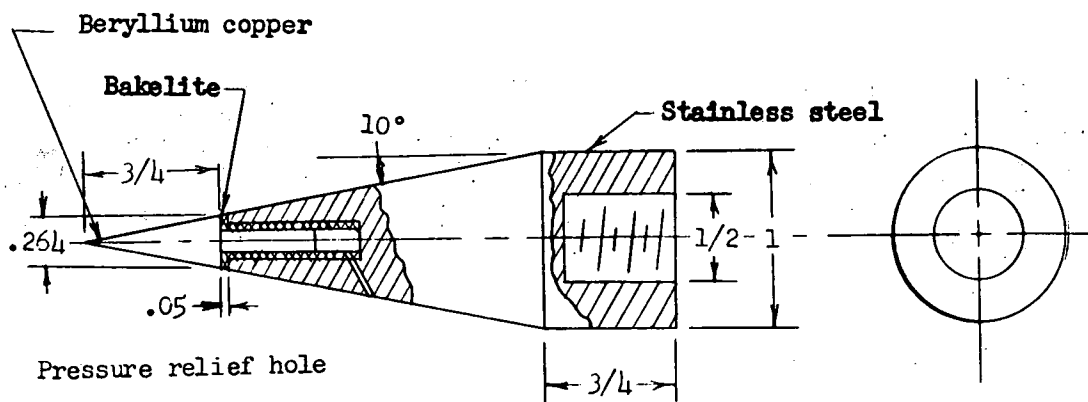


Model 2

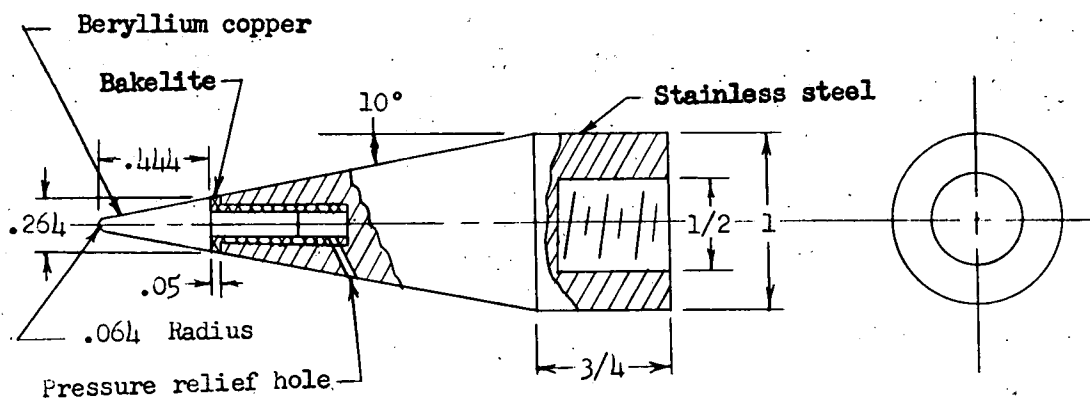
Figure 1.- Sketch of models.

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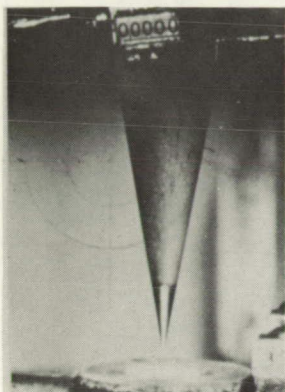
Model 3



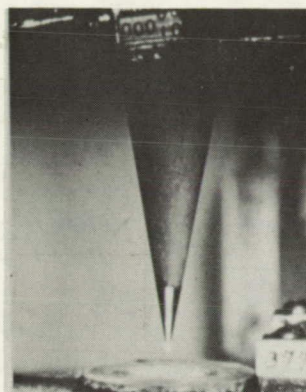
Model 4

Figure 1.- Concluded.

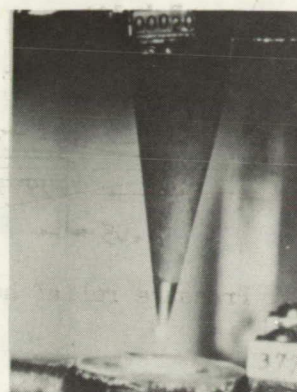
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Time in jet: 0 sec

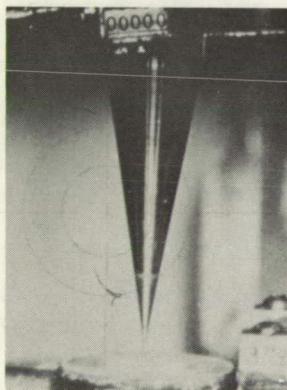


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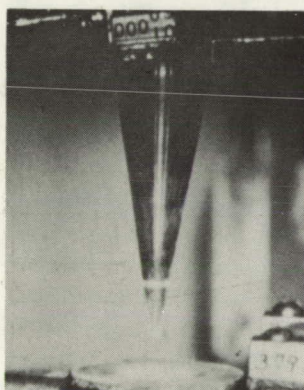


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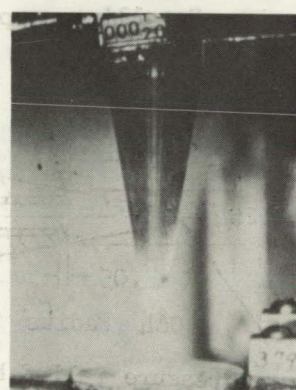
Model 1, sharp-pointed beryllium model



Time in jet: 0 sec



1 sec

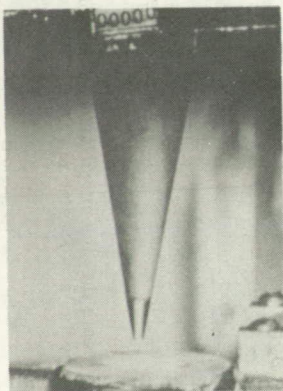


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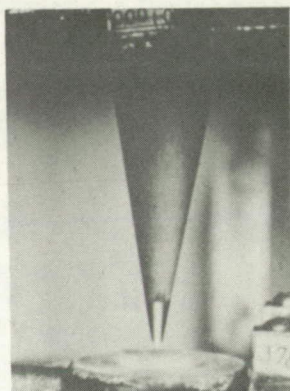
Model 3, sharp-pointed beryllium-copper model

Figure 2.- Models during test.

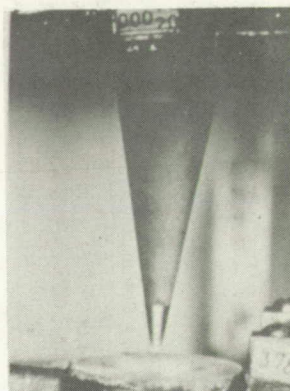
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Time in jet: 0 sec

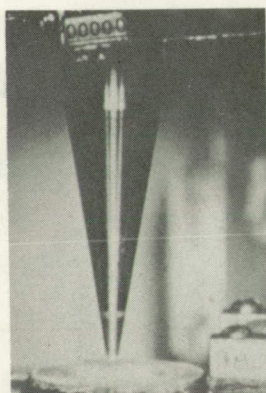


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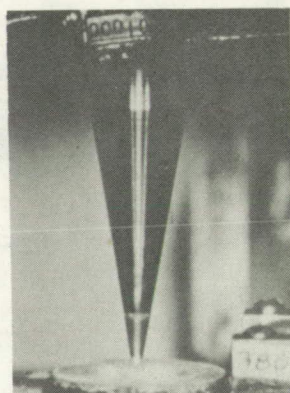


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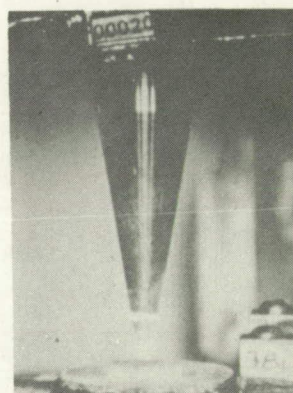
Model 2, 0.0643-inch-radius beryllium model



Time in jet: 0 sec



1 sec



2 sec

Model 4, 0.0643-inch-radius beryllium-copper model

Figure 2.- Concluded.

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